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TENSILE AND FLEXTURAL CHARACTERIZATION OF VINYL ESTER/ GREWIA ASIATICA (PHALSA) WOOD COMPOSITE

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ABSTRACT

Composite material is a material consisting of two or more physically or chemically distinct phases, suitably arranged or distributed together to get improved mechanical properties. Nowadays, a wide range of composite engineering materials shows natural fiber-reinforced polymer composite hasplayed a vital role in manufacturing industries. These composites possess a combination of superior mechanical properties as well as resistance to environmental degradation. The conventional polymer-based plastic, glass or carbon fiber materials are replaced with natural fiber due to added advantages such as ease of processing technologies, rising prices of finite resources andeco-unfriendlyconcerns. Many environmental issues can be solved by using natural fiber reinforced with polymer matrix materials. The natural fiber such as jute, coir, sisal, pineapple, ramie, bamboo, and banana are widely used as a reinforcing agent of the polymer composite. In this research, we have initiated to utilize agricultural waste natural fiber asa reinforced agent with thermosetting plastic resin (vinyl ester). High weight fraction up to 40% ofGrewia Asiatica wood fiber has been used and tested. It was found that a 30% weight fraction of Grewia Asiatica with vinyl ester composite gives maximum stiffness up to 7 Gpa and strength up to 343.6 Mpa. Further tensile and flexure characteristics have been investigated in the results and discussion section.

KEYWORDS: *Hand Layup Moulding system, Vinyl ester [VE], Grewia Asiatica/Phalsa Woodfiber & Composite*

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Original Article

1. INTRODUCTION

This delicious fruit Grewia Asiatica (called Phalsa in local language) is being cultivated in many countries in Asia, especially at a large portion of the land about 1185 hectares throughout Pakistan as shown in Figure 1[1]. All parts of this plant-like fruit, leaves, bark, fiber, and wood have ample usage, its fruit is rich in specific ingredients used for medication. It possesses great importance since the Vedic period (1500C to till date). The fresh leaves are used as animal fodder, the bark is useful as an alternative to soap and refiner for sugar, the ropes were also made from fiber removed from the bark. The final wood branches are strong and very flexible in nature, after harvesting the fruit the plants are being cut back to ground for next year's crop purpose, their branches' size varies from 2-6 meters and 0.5 to 22mm in diameter, 90 – 95% of these branches may be considered as waste product, it's 5-10% (thin branches) are used to make shafts for golf sticks, support sticks used for carrying small loads, bows, spear handles, shingles, baskets, and remaining 80 – 85% is completely wasted by burning as fuelwood purposes[2].

Figure 1: Grewia Asiatica Fruit Plant (Phalsa Plant)

Due to high flexibility, variable size and length this agriculture waste can be used at large scale to develop composite with a matrix material of plastic nature instead of wasting it as fuel. The long enlarged branches of the Grewia Asiatica possess strong tensile strength as well as high flexure modulus, can be used as a reinforcing agent in different waive form to improve its mechanical properties in making the intricate structure as per requirement. Agricultural wasted materials are being used at a large scale in making new advanced composite materials.

In current decade research has been carried out to utilize natural fiber as a reinforcing agent due to attractive mechanical as well as anti-corrosion and environmentally friendly nature of the composite. Mushtaque A. L et al (2018) have locally developed the Jute fiber of 0/90° oriented reinforced composite with the vinyl ester matrix material[3]. The developed specimens were tested to study tensile behavior and its comparison with conventional composite materials. The result reflected that the developed composite specimen possess recorded improvement in tensile properties such as Tensile strength (GPa) was improved in the range of 122.95–279.80%, Modulus of Elasticity [MOE (GPa)] was increased by 142.91–228.91%, Break Elongation (%) was raised by 289.90–425.90% and Shear Modulus (C) was enhanced from 846.69 to 1354.71%. Sanjay M.R et al (2016) worked on natural fiber composites and analyzed properties like formability, low cost, renewability and eco-friendly nature of the new range of composites by using natural fiber as a reinforced agent in composites and gained importance in commercial engineering sectors[4]. Venkatachalam G et al, (2016) studied the tensile behavior of the natural fiber reinforced with polymer matrix based composites and concluded that the maximum strength initially decreases till the critical point and then increases up to the plastic limit. Ultimate and failure stress decrease with a percentile increase in Cashew-nut shell Resin (CNSL)[5].

Emad O et al, (2016) presented the importance of composites emerging from last decade's research over natural fiber-reinforced composites[6]. The major industries like automotive, construction and packaging utilize natural fiber reinforce composites. The natural fiber-reinforced composites also satisfy the required specifications in tribology field applications due to specific fiber treatment and fiber orientation during their affirmative financial and ecological phases. Mushtaque et al, (2015) developed a Vacuum Assisted Resin Transfer Moulding (VARTM) system, to prepare the composite material specimens[7]. Cotton fabric (natural fiber) as a reinforcement agent with polymers was used. The cotton fabric (2/2 plain weave 0/90 oriented) with varying number of laminated layers was investigated and a significant improvement in mechanical characteristics was found[8].

Rajpar et al, (2014) developed cotton fibber reinforced composite specimens with the help of the hand layup process, in which the effect of cotton fiber as a reinforcing agent was examined[9]. Samples possess significant improvement in mechanical properties. Das *et al*, (2015) worked on the preparation of environment-friendly composites considering, good specific strength, less cost, lower pollutant emissions and fine energy recovery[10]. A unidirectional compressed jute fiber

sheets as reinforcement agent with matrix material (unsaturated polyester resin) composites were developed and found that the composites made from raw jute have higher tensile and flexural properties compared to the composites made from jute sliver. Saw *et al,* (2014) developed composite by using epoxy Novolac resin to study its different physical properties [11]. Azwa *et al.* (2013) stated that composite possesses the desired and preferred properties by coalescing dissimilar constituents in a cautious and judicious way. Generally, they possess higher specific modulus and high specific strength enabling them as a valuable material for automotive industries [12], [13].

Thiruchitrambalam M *et al,* (2009) stated that carbon fibers and glass fibers integrated with polyester resin are the traditional and conventional fiber-reinforced composite materials[14]. These composite materials have excellent mechanical properties but these materials cause environmental pollution due to the non-degradability of fibers. Akil *et al,* (2014) presented his study on the effect of degradation of the mechanical characteristics of natural fiber and hybrid reinforced polyester composites with a special focus on aging[15]. Their significant improvement in both strength and modulus was also observed[15]. Kalia *et al,* (2009) worked on the unidirectional Kevlar/glass fiber hybrid composites by studying longitudinal tensile strength and stretch modulus[16]. This study was focused on the tensile strength and stretch modulus of the composites;the tensile properties of pure glass fiber unidirectional composites prepared under different conditions were analyzed. Thakur V.K et *al,* (2014) concluded that industries are using reinforcement fibers that are integrated into the polymers for increasing the physical and mechanical properties of composites. These composites gaining interest from industries due to minimum weight, ease of doling out and cheaper in cost [17].Ku H *et al,* (2011) & Bamdad. B *et al* (2015) presented research on how to improve the sound strength of composites[18], [19].Unterweger. C *et al,* (2014) worked to stumble on proper stiffness of composites[20], Santos T *et al,* (2015) &X. Q Pei*et al,*(2015) reported that most composites can be developed with negligible oxidization [21] and weak friction coefficient[22].Bahadur S *et al* (1990-2015) stated about composites used in several engineering applications for their best mechanical and tribological properties, further uses are for all stuff needed by running life from home decorative pieces to space components[23]–[27].A research study was also concluded that the composites found with environment-friendly, reinforcing fibers can be achieved from renewable sources and they further express that composites also possess eco-friendly qualities [28], [29].

Astrom *et al* (1997) Provided the standard of Manufacturing the Polymer Composites, the cobalt and hardener have been added in resin as per resin–hardener ratio was 96% resin by weight, 2% hardener by weight and 2% cobalt by weight (96:2:2) [30]. In a handbook published by the Department of Defence Handbook (2002) the testing standard has been reported as a guide for composite materials[31].

In this research study, the main focus is to utilize the agricultural waste material seasonally available in abundant quantity as a reinforcing agent, as compared to other natural fiber this wastage material possess a higher rate of mechanical properties. It can be utilized in different weave forms, different orientations, possessing high flexibility in nature, naturally available in different sizes and shapes. By adding a small quantity of matrix material it can resist the environmental degradation effects.

2. MATERIALS AND METHODS

Composite material development is an emerging field of research, in this study the samples have been developed by using vinyl ester (V.E) as a matrix material and Grewia Asiatica (Phalsa) wood fiber (Agricultural waste) as a reinforcement material (first time) by using hand lay-up Moulding process system. The samples were developed on five different weight

fraction ratios to study their mechanical properties like tensile and flexure behavior. The reinforcement fiber material of uniform diameter of 5 mm was laid on a surface of a solid brass Mould of 152 by 25.4 mm and fixed it at the proper place of equal width and length as shown in Figure 2 (a & b). After proper lying up the fiber material, resin in a molten form was poured in a mold as shown in Figure 2(c) until it coversthe whole moulded area in a short span of time. A developed sample was left for 24 hours for the curing and solidification process then it was carefully de-moulded to take out specimen from mould. The sample developed by the above traditional process has got a smooth surface as shown in Figure 2 (d).

Development of Test Specimen

The 152.4mm long, 25.4mm wide and 8.0mm thick specimens were developed as per the requirement of the ASTM standard testing machine. The validation of test results was a vital issue of the developed specimens, to get appropriate results five specimens of each sample weight fraction ratio of 0:100%, 10:90%, 20:80%, 30:70% and 40:60%, (wood resin ratio) were developed by using hand lay-up process. For rapid curing process methyl ethyl ketone peroxide (MEKP) and cobalt (accelerator) from 0.5 gram to 2 gram per 100 gram of resin were used. Various types of the samples depend upon their composition were developed by separately developed molds as mentioned below.

Mould A: Development of pure vinyl ester KrF 1001 Specimen. In this setup, the five pure vinyl ester samples were developed as shown in FigURE 3A.

Mould B: Development of composites Vinyl Ester with 10% by weight Grewia Asiatica (Phalsa) wood fiber. In this setup, five samples of mentioned percentile weight fraction reinforced material with matrix material were developed as shown in Figure 3B.

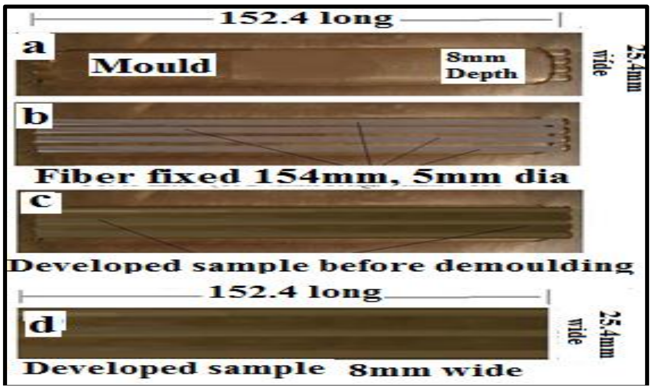

Figure 2: (a) Bross Mould (b) Placement of Natural Fiber in Mould (c) Resin poured in Mould (d) Prepared Sample

Mould C: Development of composites Vinyl Ester with 20% by weight of Grewia Asiatica (Phalsa) natural wood fiber. In this setup, five samples by adding 20% by weight reinforced material with matrix material were developed as shown in Figure 3C.

Mould D: Development of composites Vinyl Ester with 30% by weight Grewia Asiatica (Phalsa) wood fiber, In this setup, five samples by adding 30% reinforced material with matrix material were developed as shown in Figure 3D.

Mould E: Development of composites Vinyl Ester with 40% by weight Grewia Asiatica (Phalsa) wood fiber. In this setup, five samples by adding up to 40% reinforced material with matrix material were developed as shown in Figure 3E.

Test Setup

The mechanical properties of the composite samples have been identified by conducting standardized tests. Standard SSTM-20KN UTM machine for tensile behavior and CSE126 Flexure Testing Machine for flexural behavior tests were selected.

Following mechanical characters has been observed during tests:

- Yield (N)
- Yield Strength (MPa)
- Tensile (N)
- Tensile Strength (MPa0
- MOE (MPa)
- Break Elongation (%)
- Flexure Strength (MPa)
- Flexure Modulus (MPa)

3. RESULTS

In this experimental study, samples were tested with and without reinforcement material to check their tensile and flexural behavior.

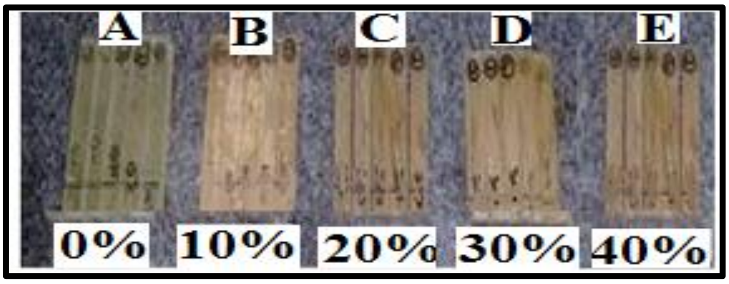

Figure 3: (A)pure n VE (B)Grewia Asiatica 10% (C) Grewia Asiatica 20% (D)Grewia Asiatica 30% (E)Grewia Asiatica 40%

Table 1. Results of tensile and flexure tests of pure matrix material

S. No	Plain Vinyl Ester	Strip 1	Strip 2	Strip 3	Mean
01	Yield(N)	39.32	41.07	39.56	39.98
02	Yield Strength (MPa)	58.19	59.94	58.43	58.86
03	Tensile (N)	74.19	75.94	74.43	74.85
04	Tensile Strength (Mpa)	85.50	86.25	84.74	85.50
05	MOE (Mpa)	1798.07	1799.82	1798.31	1798.73
06	Break Elongation (%)	4.31	4.01	4.07	4.13
07	Yield Elongation (%)	1.99	1.86	2.13	1.99
08	Tensile Elongation (%)	4.31	4.01	4.07	4.13
09	Flexure Yield (Mpa)	113.39	112.18	113.21	112.93
10	Flexure Strength (Mpa)	142.03	143.02	142.43	142.49
11	Flexure Modulus (Mpa)	3570.03	3569.9	3571.45	3570.46

Pure Vinyl Ester Resin Sample Test

Samples of pure virgin vinyl ester (VE) resin of size 152.4 mm long, 25.4 wide and 8mm thick were selected to test. Three consecutive tests of the Specimen were conducted, tensile and flexural behaviors of those conducted tests were recorded as shown in Table 1.

Composite Material Sample Test

Composite material samples reinforced with 10%, 20%, 30% and 40% weight fraction of Grewia Asiatica (Phalsa) natural wood fiber has been tested individually and the average value of (five samples) of each mechanical properties recorded on the various machines are reported in Table 2.

From Table.2, the result reflects that the tensile strength obtained as 252.22 MPa, 294.46 MPa, 343.68 MPa and 324.44 MPa for 10%, 20%, 30%, and 40% reinforced composites respectively. While the modulus of elasticity has recorded as 5306.42 MPa, 6253.57 MPa, 7468.38 MPa and 6953.60 MPa for 10%, 20%, 30%, and 40% reinforced composites correspondingly. Whereas the tensile elongation [%] is, attain 4.37%, 4.34%, 4.29% and 4.28% for 10%, 20%, 30% and 40% reinforced composites as well Although the Flexural Yield (MPa) is, attain 335.74 Mpa, 379.39 Mpa, 390.77 Mpa and 418.12 Mpa for 10%, 20%, 30% and 40% reinforced composites similarly, Though the flexural strength (MPa) was deducted as 415.07 Mpa, 460.73 Mpa, 465.34 Mpa and 479.30 Mpa for 10%, 20%, 30% and 40% reinforced composites.

Table 2. Mechanical Properties of Composite Samples and Plain VE

Mechanical Properties		Plain VE	Reinforced Samples			
			10% GAPWF	20% GAPWF	30% GAPWF	40% GAPWF
01	Yield (N)	39.98	116.36	136.01	159.24	151.03
02	Yield Strength (Mpa)	58.86	172.06	200.48	234.35	221.90
03	Tensile (N)	74.85	219.26	255.87	298.82	282.13
04	Tensile Strength (Mpa)	85.50	252.22	294.46	343.68	324.44
05	MOE (Gpa)	1798.73	5306.42	6253.57	7468.38	6953.60
06	Break Elongation (%)	4.13	4.37	4.34	4.29	4.28
07	Yield Elongation (%)	1.99	2.01	2.00	1.94	2.04
08	Tensile Elongation (%)	4.13	4.37	4.34	4.29	4.28
09	Flexure Yield (Mpa)	112.93	335.74	379.39	390.77	418.12
10	Flexure Strength (Mpa)	142.49	415.07	460.73	465.34	479.30
11	Flexure Modulus (Mpa)	3570.46	10207.95	11228.74	12688.48	14845.52

Figure 5: Percentile Improvement in Mechanical Characteristics of Composite Against Pure VE

However the Flexural Modulus (MPa) has been obtained as 10207.95 Mpa, 11228.74 Mpa, 12688.48 Mpa and 14845.52 Mpa for 10%, 20%, 30%, and 40% reinforced composites.

From Table 2 it was observed that 30 % weight fraction of reinforced material possesses high strength and high stiffness as compared to all weight friction ratios used in this study. Figure 5 clearly shows percentile improvement in various

mechanical characteristics of the developed composite samples.

It has been observed that developed composite possess more than 400 % improvement tensile strength as well as 343% improvement in modulus of elasticity. In the flexure test, maximum strength was deducted in a 40 % weight fraction ratio of reinforced material as 336.37 % and that of flexure modulus as 415.79 %.

Comparison of Tensile Characteristics 30% Grewia Asiatica Wood Composite with related Composite Material

From this experimental investigation, it was observed that a 30% weight fraction of Grewia Asiatica (Phalsa) wood fiber with matrix material indicated optimized values of important mechanical properties as mentioned in Table.2. To validate the optimized results it was necessary to compare the detected results with other related composites[9] and[32] as shown in Table 3.

Table 3: Comparison of Important Mechanical Properties with Other Related Composites

Properties	U.D CF[9]	Kevelor[32]	Developed
Tensile Strength (MPa)	290.28	480.05	343.68
MOE (MPa)	4132.35	2989.37	7468.38
Tensile Elongation (%)	6.70	1.60	4.29

From Table 3 it has been observed that developed composite material has more visible improvement in tensile characteristics as compared to closely related composites.

4. CONCLUSIONS

In this research main focus was on how to utilize agricultural waste into a productive manner. The agricultural crop Grewia Asiatica (Phalsa) when its season researches to saturation stage it is necessary to cut it and evacuate the land to prepare for another crop on time. Huge wastage of this agricultural crop possesses attractive mechanical properties like high tensile strength and attractive flexibility in its nature. This research has opened a new door to utilize this agricultural waste and produce a composite material with added properties. To get proper utilization of this agriculture waste, samples were developed and tested to analyze its mechanical properties.

Findings of the present study of tensile and flexure characteristics of developed composites show that the percent weight composition of the composite can be calculated as a function of natural fiber and vinyl ester mixing ratio. Vinyl ester mixing ratio can be utilized in the design of natural fiber composite (i) its tensile behavior varies with fiber, vinyl ester weight fraction (ii) Flexure modulus of the composite as evaluated experimentally, constantly increases up to a certain limit. Thus all together study points towards the potential use of composites with optimized natural fiber mixing.

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